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DISCLOSURE TITLE: Biasing Means for Contactless Laser Inspection Testing of Circuit Packages

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DISCLOSURE TEXT:

- A technique is described whereby limitations of laser photoemission testing of wiring are removed by contacting and properly biasing the wiring to be tested. By contacting and biasing the wiring, using techniques such as metal-clad flexible sheeting, problems associated with wire charging and materials variations are removed, for laser photoemission inspection testing of the wired packages.
- Contactless laser testing, for testing of logic states and switching transient waveforms on high speed semiconductor chips, has proved to be quite feasible. A critical application in packaging is the inspection of wiring for shorts and opens as well as for imperfections which may lead to shorts or opens during the functional operation of the circuit package. The concept

described herein
extends the laser testing to carry out this type of inspection in
both single- point scanning and in full-chip modes of operation.

- The concept takes advantage of the fact that the photoelectron
threshold energy for exciting emission from the metal wiring,
typically 4 to 5 eV, is considerably below that for causing emission
from the surrounding insulating material of the package. For
example, Al_2O_3 has a band gap of 7.3 eV, so the threshold must be at
least this large and polymer materials should be similar. With laser
photon energies just above the threshold for the metal but below that
of the insulator, high contrast inspection testing by laser-induced
photoelectron emission can be expected. ***** SEE ORIGINAL DOCUMENT
*****

The band alignments for such an ideal situation in the
insulating material of the package is depicted in Fig. 1(a).
With a
perfect host material, the Fermi level EF would be at the middle of
the energy gap EG which separates the valence band maximum Eval and
the conduction band minimum Econd . The level for vacuum emission is
the vacuum level Evac, which is normally just above Econd . Since
the material is assumed ideal, there are no electronic states in the
energy gap, so the highest energy occupied electron states lie at
Eval, and the minimum energy required to raise electrons above Evac
is the photoelectric threshold Ephoto = Evac - Eval . If any low
concentration of electrons were available within the band gap,

electron emission would be possible at threshold excitation energies starting at Ethermal = Evac - EF, because the highest such occupied electron states in the gap would be at EF .

- There are two contrasting situations which limit this approach: non-ideal band alignments due to defect states and ideal band alignments with electronically isolated wiring. Defects and non-ideal band alignment

Band alignment may be different either at the surface or in the bulk of the insulating packaging material, as shown in Fig. 1(b). Here, a sufficient concentration of defect states exist within the band gap to shift the Fermi level away from its midgap position. With enough defects, EF moves toward and eventually to the energy position of the defect level Edefect, and thermionic emission threshold changes toward or to E'thermal = Evac - Edefect . Furthermore, a new value of E'photo develops which lies below the energy of Ephoto . Such defects may be intrinsic to the nature of the insulating packaging material.

Defects are associated with non-stoichiometry accompanying typical growth processes, as the oxygen deficiency which makes ZnO always n-type, or they may be due to impurities in the bulk or on the surface. The change in bond alignment for real situations results in that some photoelectrons from the defect states will be excited together with those from the metal wiring, so that contrast between the metal and the insulator will be reduced. The contrast degradation will depend on the height of the defect density.

- Ideal band alignments with electrically isolated wiring If a few defects exist, it is expected that band alignments not only follow the characteristics of Fig. 1(a), but the resistivity of the insulator should be extremely high. For an isolated metal line of capacitance C, removal of charge Q by photoelectron emission from the line will shift the potential of the line to a V = Q/C. If this potential is comparable to the kinetic energies of the photoelectrons being emitted, this charging will cause microfields around the emission point. The charge lines will tend to attract the low energy photoelectrons until no more electrons can escape. The signal is therefore turned off by the charging.
- In estimating the degree of charging expected, typical capacitances for wiring lines on the packages range from 1 fF (10-15) to 1 pF (10-12F). For a signal-to-noise ratio of 30, 103 electrons must be measured per inspection point. Assuming that all photoelectrons emitted are collected and utilized in the measurement process, this corresponds to +0.2 mV and +200 mV charging for 1 pF and a 1 fF capacitance lines, respectively. By the time enough points are measured for a real inspection of the physical integrity of the line, the charging of the line is very significant. For example, a 10 mm. line which is 25m in width inspected with 5m resolution requires 104 points to be inspected. This would yield voltage shifts due to charging which are very large compared to the photoelectron kinetic energies used.

It would therefore be necessary

to discharge the lines many times during the inspection of the package or else to wait for the lines to discharge.

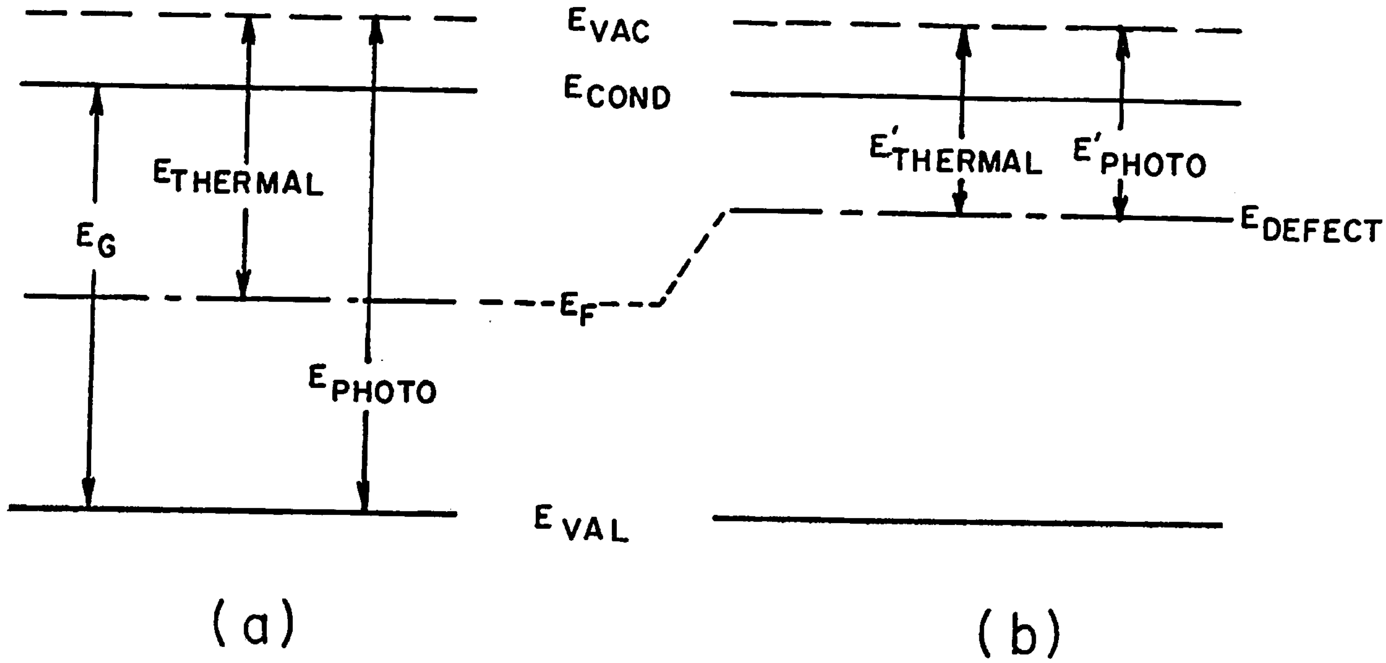
- It is evident that both cases, real and ideal, will lead to problems with laser photoemission inspection testing of the package wiring; with significant defects present, the metal vs. insulator contrast will be degraded, while with few or no defects the charging problem will become evident. By contacting the wiring with a controlled voltage supply, both problems can be overcome. In the case of real insulators, the metal lines can be biased by several volts to gain the desired contrast, independent of the insulator. In the case of near-ideal insulators, such biasing will maintain the potential of the metal lines without shifts due to charging. Also, the lines can be biased an amount appropriate to achieve high contrast/discrimination between photoelectrons emitted from the metal lines and those from the insulator.

- The required biasing of the metal wires to be inspected can be accomplished by contacting a large number of wires on the package at sites away from the portion of the package to be tested. Since C4 and EC pads, as shown in Fig. 2, are accessible at each chip site and most are interconnected from one site to another, the concept proposes shorting all of the pads together on the package everywhere but at the chip site being tested. This may be accomplished by pressing a metal- clad flexible sheet, such as copper plated on MYLAR*, against the package, where a portion of the sheet has been cut out at the chip site to be tested.

- In this way, all portions of the C4s and ECs at the site under test will reach voltage Vbias, except those few which do not contact either portions to another chip site, either directly or indirectly.

Once the sheet is attached and the biasing is accomplished, the surface wiring at site B can be inspected by the laser testing technique. The measured photocurrents reflect the potential of the point addressed by the laser. Because the wires are electronically connected to a voltage bias source, the measured potentials are not affected by charging of the wire in the package or contrast variations due to unknown photothresholds of the insulating material.

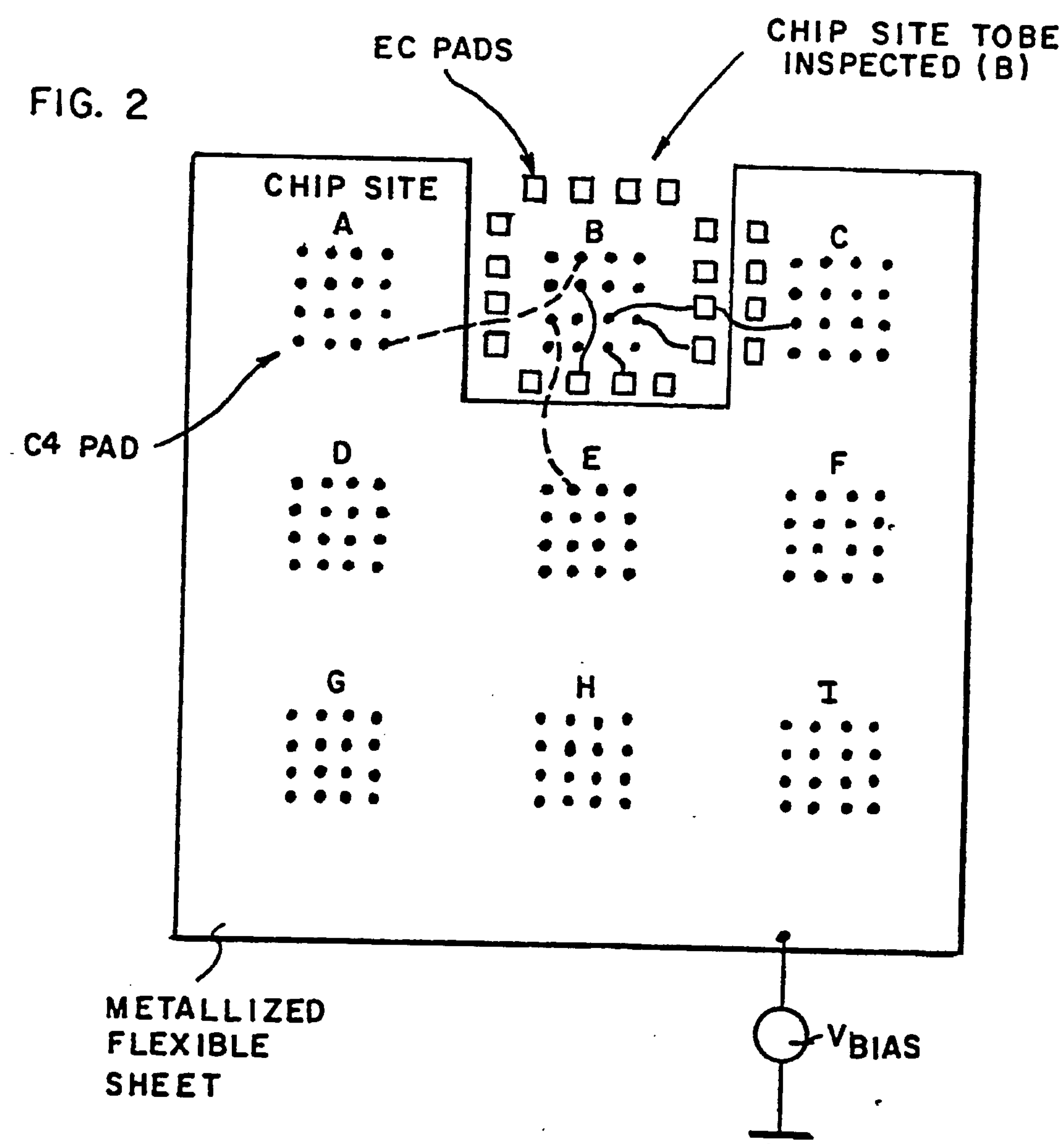
* Trademark of E. I. du Pont de Nemours & Co.



E_{VAC}
E_{COND}
E_G
$E_{THERMAL}$
E_F
E_{PHOTO}
E_{VAL}
$E'_{THERMAL}$
E'_{PHOTO}
E_{DEFECT}
(a)
(b)

FIG. 1

FIG. 2



EC PADS
CHIP SITE TOBE INSPECTED (B)
CHIP SITE
A
B
C
C4 PAD
D
E
F
G
H
I
METALLIZED FLEXIBLE SHEET
V_{BIAS}